Non-repeated and Non-uniform Width Seal Ring Structure

FIELD OF THE INVENTION

The present invention relates generally to an improved method of forming a seal ring structure and more specifically to a method for forming a seal ring structure having good moisture protection and die corner peeling and crack prevention.

BACKGROUND OF THE INVENTION

An edge seal is commonly used as a mechanical barrier to contaminants introduced in the die sawing process, including moisture that may disrupt the performance of the integrated circuit device. A conventional edge seal consists of a combination of metal lines connected by line-type vias. Such an edge seal does not protect the chip corners from delaminating and cracking. During singulation, cracks sometimes develop, then propagate through the seal ring during reliability testing. Delaminations have been found to occur near corners where stress is highest.

Fig. 1 illustrates a top view of a conventional seal ring structure. Seal ring 11 encloses die 60. As shown in Fig. 2, seal ring 21 has a sloped corner area instead of a sharp corner to decrease stress. Fig. 3 shows a seal ring 31 having slots 33 within it. The slots may or may not help to decrease stress. Fig. 4 shows a repeated redundant crack stop seal ring 41. This seal ring has the disadvantage of taking up a lot of design space, not only at the corners, but along the whole length of the seal ring. It is desired to find a method of forming an edge seal that will not delaminate or crack.

Co-pending U.S. Patent Application Serial Number 09/989,837 filed on 11/20/01 and assigned to the same assignees as the present invention describes a seal ring having alternating widths along its length. U.S. Patents 6,300,223 to Chang et al and 5,831,330 to Chang teach the use of plugs in a seal ring to prevent cracking. U.S. Patent 5,834,829 to Dinkel et al describes the redundant seal ring structure of Fig. 4. U.S. Patent 6,028,347 to Sauber et al show trenches formed outside the seal ring at the corners. U.S. Patent Application 2001/0030358 to Okada et al teach a method of seam welding of the seal ring at the corners to prevent cracking.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved method for forming a seal ring structure in the fabrication of integrated circuits.

Another object of the present invention is to provide a method for forming a seal ring structure having a wider corner structure.

A further object of the invention is to provide a method for forming a seal ring structure having one width at the corners and a smaller width along the edges of the die.

According to the objects of the present invention, a method of forming an improved seal ring structure is achieved. A continuous metal seal ring is formed on a substrate along a perimeter of a die wherein the metal seal ring encloses device structures, wherein the metal seal ring is parallel to the edges of the die and sloped at the corner of the die so as not to have a sharp corner, and wherein the metal seal ring has a first width at the corners and a second width along the edges wherein the first width is wider than the second width.

Also according to the objects of the invention, an improved seal ring structure is achieved. The seal ring comprises a plurality of layers of metal lines formed overlying a substrate and a plurality of metal vias through intermetal dielectric layers between the layers of metal lines wherein the metal vias interconnect the metal lines and wherein the plurality of layers of interconnected metal lines forms a continuous seal ring around a die and wherein a first width of the metal lines at a corner of the die is wider than a second width of the metal lines at edges of the die.

Also according to the objects of the invention, an improved semiconductor device is achieved. The semiconductor device comprises semiconductor device structures formed in and on a substrate and a seal ring enclosing the semiconductor device structures forming a single die wherein a first distance between the semiconductor device structures and a corner portion of the seal ring is smaller than a second distance between the semiconductor device structures and an edge portion of the seal ring.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more clearly understood from the following description taken in conjunction with the accompanying drawings in which like reference numerals designate similar or corresponding elements, regions and portions in which:

Figs. 1 through 4 illustrates top views of portions of seal ring structures of the prior art.

Fig. 5 is a cross-sectional view of a preferred embodiment of the present invention.

Figs. 6, 7, and 8A through 8C are top views of several preferred embodiments of the present invention.

Fig. 9 is a top view of an entire seal ring of the present invention.

Fig. 10 is a cross-sectional view of a seimconductor device structure of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 5 shows a cross-section of a metal seal ring structure. A seal ring is a continuous metal structure outside of all of the active devices of the integrated circuit, except perhaps those devices used for temperature testing. Tungsten plugs or copper vias 16, for example, through an intermetal dielectric layer 18 connect metal lines 14 together,

above substrate 10, to form a seal ring. Multiple layers of metal lines interconnected with vias are formed and capped with a passivation layer 20. The active devices are formed within the interior of the die. The die is cut at the scribe line 26. The seal ring structure is used on all dies to prevent moisture penetration into the interior of the die and to prevent crack propagation. It has been found that cracks and delaminations occur near corners where stress is high.

In a key feature of the present invention, the corners of the seal ring are strengthened by adding width without increasing the width of the rest of the seal ring. Increasing the width of the entire seal ring decreases the space available for integrated circuit structures on the die.

Fig. 6 shows one preferred embodiment of the present invention. Seal ring 61 has been formed to enclose the entire die 60. Active semiconductor device structures, not shown, are formed within the seal ring as is conventional in the art. The seal ring has a first width A on the edges of the die and a second width B at the corner of the die. The corner width B is thicker than the width A. Preferably, the corner portion of the seal ring width is about 1.5 times the width of the edge portion of the seal ring or greater.

Fig. 7 shows a second preferred embodiment of the present invention. Seal ring 71 has a first width A on the edges of the die and a second width B at the corner of the die. The corner width B is thicker than the width A. In this embodiment, the wide corner area covers the entire corner section of the seal ring. In Fig. 6, the wide corner area covers only the central portion of the corner section.

Fig. 8A shows a third preferred embodiment of the present invention. Seal ring 81 has a first width A on the edges of the die and a second width C at the corner of the die. The corner width C is thicker than the width A. In this embodiment, the wide corner area covers the entire corner section of the seal ring. Also in this embodiment, a slot 83 is formed within the wide corner area. The slot can further reduce stress caused by the large wide metal corner section. Figs. 8B and 8C show other examples of slot and/or hole formations that can be used to reduce metal stress. It will be understood by those skilled in the art that a number of different slot and/or hole configurations could be used in the process of the present invention.

Fig. 10 shows a top view of a single die of the invention. The seal ring 71 encircles the die 60. The embodiment of Fig. 7 is shown in this figure. It will be understood that all embodiments of the seal ring surround the die as shown in Fig. 10. Fig. 9 illustrates a cross-section of the seal ring 71, for example, as illustrated in Fig. 5. Device structures such as gate electrode 92, source and drain regions 94, metal vias 96, and metal lines 98 are shown. The semiconductor device structures shown in Fig. 9 are examples of the device structures that comprise the integrated circuit device 60 shown in Fig. 10. The distance D between the semiconductor devices and the seal ring may be shorter in the corner region of the die than it is on the edge portions of the die because the seal ring width is increased in the corner region. The advantage of increasing the seal ring width only in the corner region is to increase the die active circuit area.

The improved edge seal structure of the present invention provides stress relief at the chip corner and prevents chip corner delamination during cutting as well as providing good moisture protection to the device.

While the present invention has been particularly shown and described with reference to the preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and detail may be made without departing from the spirit and scope of the invention.

What is claimed is: